The Global Geodetic Observing System

Richard S. Gross

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California, USA

GGOS Days

October 31 to November 2, 2017
Vienna, Austria

International Association of Geodesy

- The mission of the IAG is to advance geodesy
- This mission is performed by its components
  - Commissions and Inter-commission Committees
  - Services
  - Global Geodetic Observing System (GGOS)
- IAG Commissions & Inter-commission Committees
  - Represent the major fields of geodetic research within the IAG
  - Represent the IAG in all relevant scientific matters
    - Commission 1: Reference Frames
    - Commission 2: Gravity Field
    - Commission 3: Earth Rotation and Geodynamics
    - Commission 4: Positioning and Applications

IAG Services

- Organize the collection and reduction of geodetic observations
  - Create the geodetic products needed for scientific research and societal applications
- Geometry
  - IERS, IGS, IVS, ILRS, IDS
- Gravimetry
  - IGFS, BGI, ISG, IGETS, ICGEM, IDEMS
- Oceanography
  - PSMSL
- Standards
  - BIPM

Global Geodetic Observing System

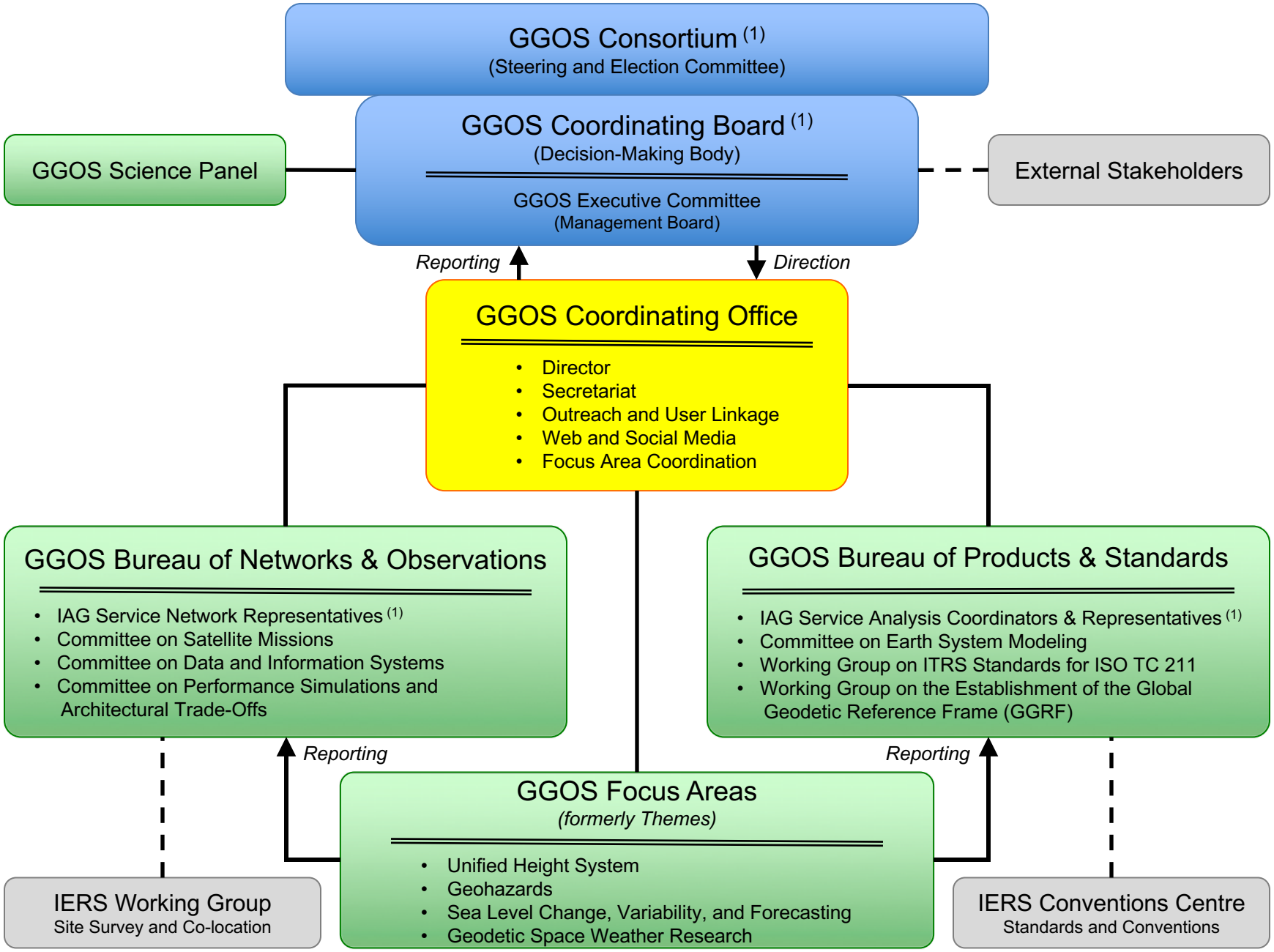
- Established by IAG
  - 2003 as IAG Project; 2007 as full component of IAG
- *The* observing system of the IAG
  - Organize the technique-specific Services under one unifying umbrella
  - Form a comprehensive geodetic observing insrument
  - Integrate the hitherto separate pillars of geodesy (shape, rotation, and gravity) into one consistent observing system
- Provide the geodetic expertise and infrastructure needed to monitor the Earth system and to conduct global change research
  - IAG Commissions and Services are the backbone of GGOS
- Represents IAG in GEO & contributes to GEOSS

GGOS Mission

We live on a dynamic planet in constant motion that requires long-term, continuous quantification of its changes in a truly stable frame of reference.

The mission of GGOS is:

- *to provide the observations needed to monitor, map and understand changes in the Earth's shape, rotation and mass distribution;*
- *to provide the global geodetic frame of reference that is the fundamental backbone for measuring and consistently interpreting key global change processes and for many other scientific and societal applications;*
- *to benefit science and society by providing the foundation upon which advances in Earth and planetary system science and applications are built.*



(1) GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

Bureau of Networks and Observations

Bureau of Networks and Observations

- Provide a forum for the Services and Standing Committees/Working Groups to share and discuss plans, progress, and issues, meetings in conjunction with annual AGU and EGU.
- Advocate for new and increased network participation, encouraging formation of new partnerships to develop new sites, monitored the status of the networks; meetings and communications held with representatives from Russia, Italy, Brazil, Japan, Spain, France, Korea, and Saudi Arabia to discuss implementation of new stations and upgrade of legacy stations.
- Continue the Bureau's "Call for Participation in the Global Geodetic Core Network: Foundation for Monitoring the Earth System"; 19 submissions have been received covering 114 sites that include legacy sites, new technology co-location and core sites, sites under development, and sites offered for future participation; a number of new sites plan to join once they are operational.

- See: http://www.ggos.org/Components/BNO/

Slide provided by Mike Pearlman

Bureau Activities

- Maintain and update the “Site Requirements for GGOS Core Sites” document (with the IAG Services); the next major step will be to include the requirements for the gravity field once it is fully documented by the IGFS and the IGRF working group; Work with the IGFS in the definition of its requirements.
- Advocate for the GGOS integrated global geodetic ground-based infrastructure through talks and posters at AGU, EGU, AOGS, APSG (China), JpGU-AGU, IAG, etc. and meetings and special presentations at GSI (Japan), IMPE (Brazil), IAP (Russia) etc.; support efforts to integrate relevant parameters from other ground networks (gravity field, tide gauges, etc.) into the GGOS network to support GGOS requirements.
- Work with the BP&S and the IGFS to help define the gravity field and unified height systems measurement requirements and encourage deployment of the field measurement systems.

Slide provided by Mike Pearlman

Bureau Activities

(Standing Committees and Working Groups)

- **Standing Committee on Performance Simulations & Architectural Trade-Offs (PLATO) (Joint with Commission 1)**

  Simulations and analyses to estimate how the data products will improve over time as the infrastructure improves. The next survey of current and projected network station capabilities will be undertaken in the second half of 2017. The results from the survey will be used to project network data quality capability 5 and 10 years ahead. Simulations on the e-GRASP/Eratosthenes mission and other co-location missions to strengthen the case for support and for network planning.

- **Standing Committee on Data and Information**

  Development and implementation of a GGOS metadata system in two stages: a stage-one scheme (hosted by CDDIS) for GGOS and GGOS-relevant data products planned for demonstration by the end of 2017, and a longer term, stage-two implementation, for the full GGOS requirements including site and instrument information, based on an XML metadata scheme under development by the Geoscience Australia, UNAVCO, and the IAG.

Slide provided by Mike Pearlman

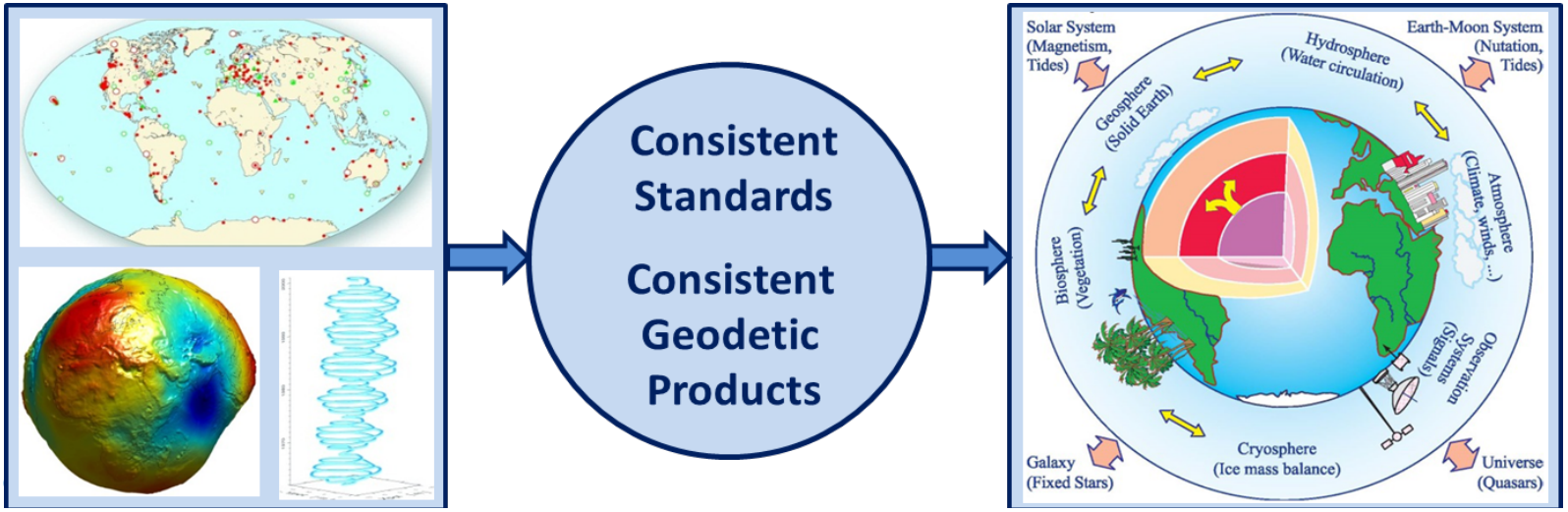
Bureau of Products and Standards

GOS Bureau of Products and Standards (BPS)

The BPS supports GGOS in its key goals to obtain consistent products describing the geometry, rotation and gravity field of the Earth.

Mission and objectives

- to serve as contact and coordinating point for the homogenization of IAG/GGOS standards and products;
- to keep track of the adopted geodetic standards and conventions across all IAG components, and initiate steps to close gaps and deficiences;
- to focus on the integration of geometric and gravimetric parameters and to develop new products, needed for Earth sciences and society.



Slide provided by Detlef Angermann

BPS Inventory

The BPS has compiled an inventory on standards and conventions used for the generation of IAG products:

- Review of numerical standards;
- Focus on IAG products: CRS/CRF, TRS/TRF, EOP, GNSS satellite orbits, gravity and geoid, heights;
- Assessment of the present status, identification of gaps, recommendations.

BPS inventory is published in the **IAG Geodesist's Handbook 2016**:

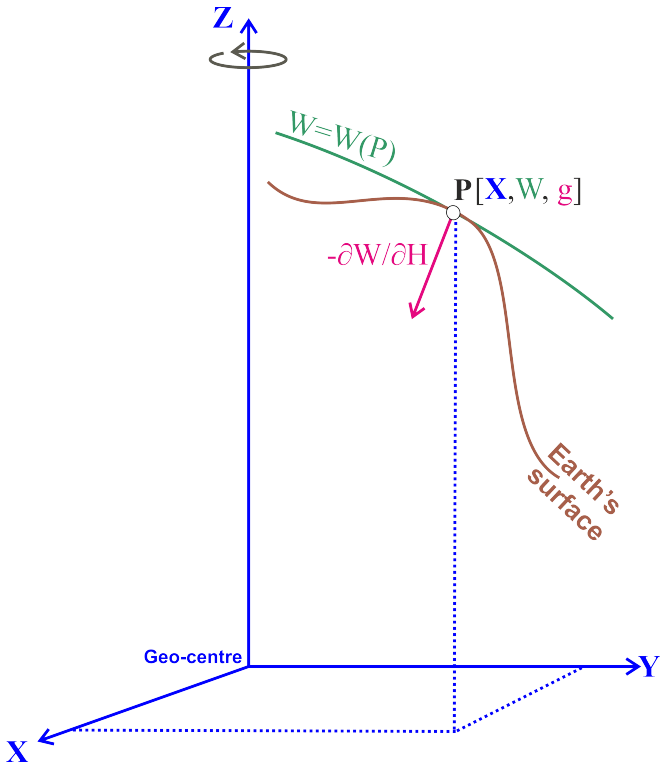
Angermann D., Gruber T., Gerstl M., Heinkelmann R., Hugentobler U., Sánchez L., Steigenberger P.: **GGOS Bureau of Products and Standards: Inventory of standards and conventions used for the generation of IAG products**. In: Drewes H., Kuglitsch F., Adám J. (Eds.) The Geodesist's Handbook 2016. Journal of Geodesy 90(10), 1095-1156, 10.1007/s00190-016-0948-z, 2016

Slide provided by Detlef Angermann

Focus Area 1
Unified Height System

Objective

A main objective of the International Association of Geodesy (IAG) and its Global Geodetic Observing System (GGOS) is the implementation of an integrated Global Geodetic Reference Frame (GGRF) that supports the consistent determination and monitoring of the Earth's geometry, rotation and gravity field with high accuracy worldwide.



The GGRF includes:

- Geocentric Cartesian coordinates $\mathbf{X}$, $\dot{\mathbf{X}}$
- Gravity vector $\mathbf{g}$, $\dot{\mathbf{g}}$
- Potential of the Earth's gravity field W, $\dot{W}$
- Physical height H, $\dot{H}$

The GGOS Focus Area Unified Height System concentrates on the determination of a unified reference system for gravity, potential, and physical heights.

Slide provided by Laura Sanchez

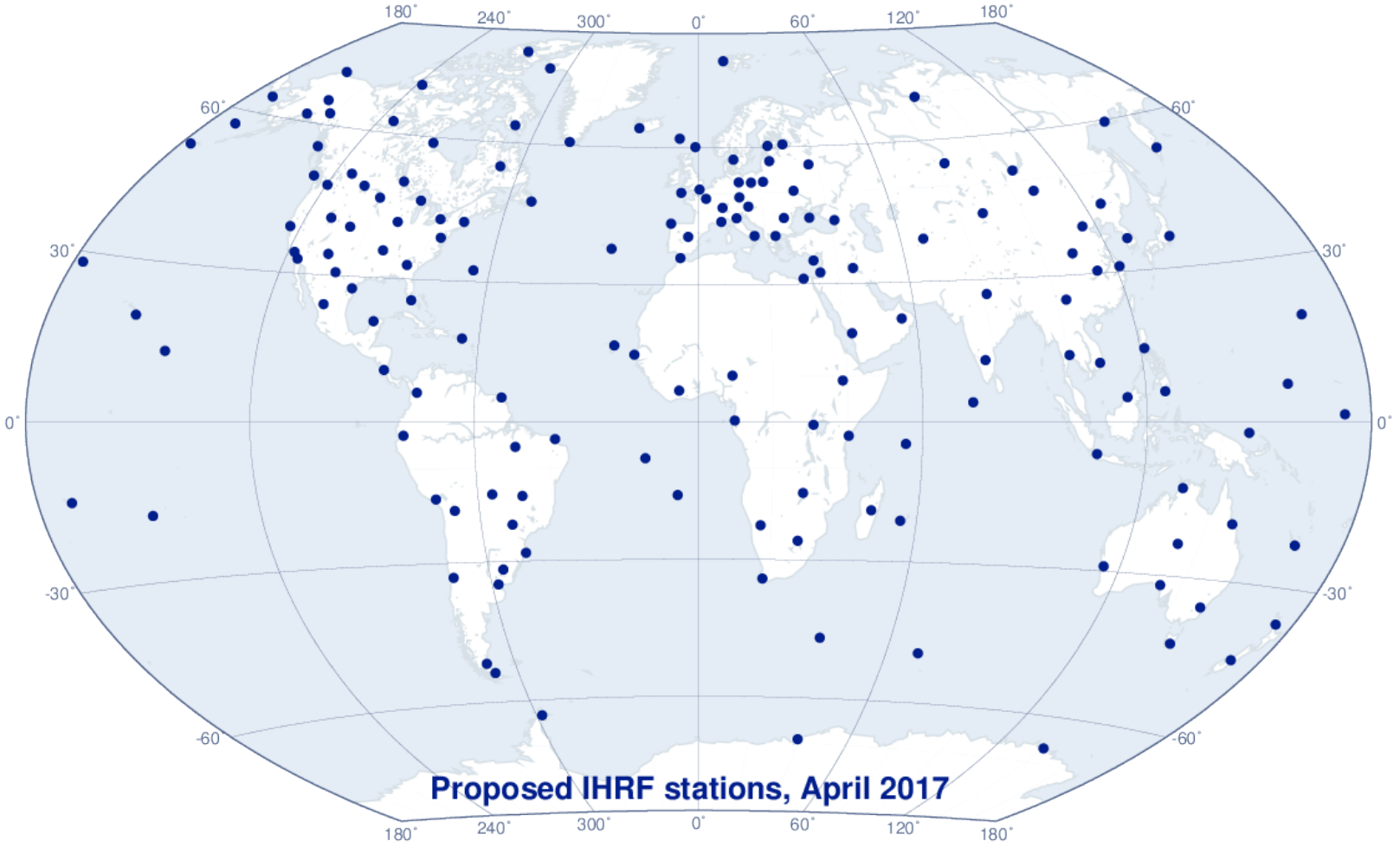
Present activities

Implementation of the International Height Reference System (IHRS) and its realization IHRF (International Height Reference Frame) introduced by the IAG Resolution No. 1, Prague, July 2015. This implies:

- Identification of standards, conventions and procedures required to ensure consistency between the definition (IHRS) and the realization (IHRF): fundamental parameters, datum realization, time-depend variations, etc.
- Characteristics of the reference network, station distribution, specifications for procedures and computations, selection of data, etc.
- Relationship between the IHRS and the existing height systems: vertical datum unification strategies.
- Collocation of the IHRF with other geodetic reference frames like the GGOS core network, the ITRF, the new Global Absolute Gravity Reference System (see IAG Resolution 2, Prague 2015).
- Contributions of the IHRF to the GGRF (UN GGRF resolution 2015).

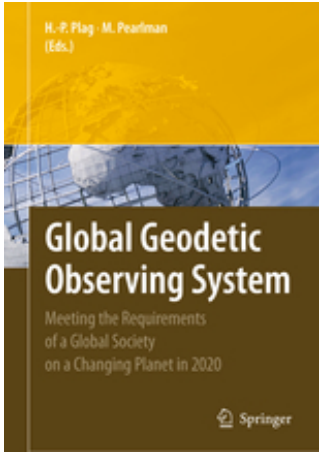
Slide provided by Laura Sanchez

Recent achievements: First proposal for the IHRF reference network (Apr. 2017) and computation of potential values (Aug. 2017)



Slide provided by Laura Sanchez

Focus Area 2
Geohazards



The Vision: GGOS2020

The ***Global Geodetic Observing System (2009)*** set a path to develop and apply geodetic science, technology, and infrastructure to mitigate our vulnerability to natural hazards.

Example: Tsunami Warning

The GGOS Geohazards Initiative **GNSS Augmentation for Tsunami Early Warning** (GATEW) builds upon the **IGS Real Time Service (GPS-RT)** and **IGS Multi-GNSS Experiment (M-GEX)**.

The GATEW Working Group will be a catalyst and motivating force to define requirements, identify resources, and encourage international cooperation.

Slide provided by J. LaBrecque

GATEW Initiative Highlights:

- The GGOS laid the foundation for the GATEW Initiative through formal recommendations by the IGS, IUGG, IOC, and the APSG.

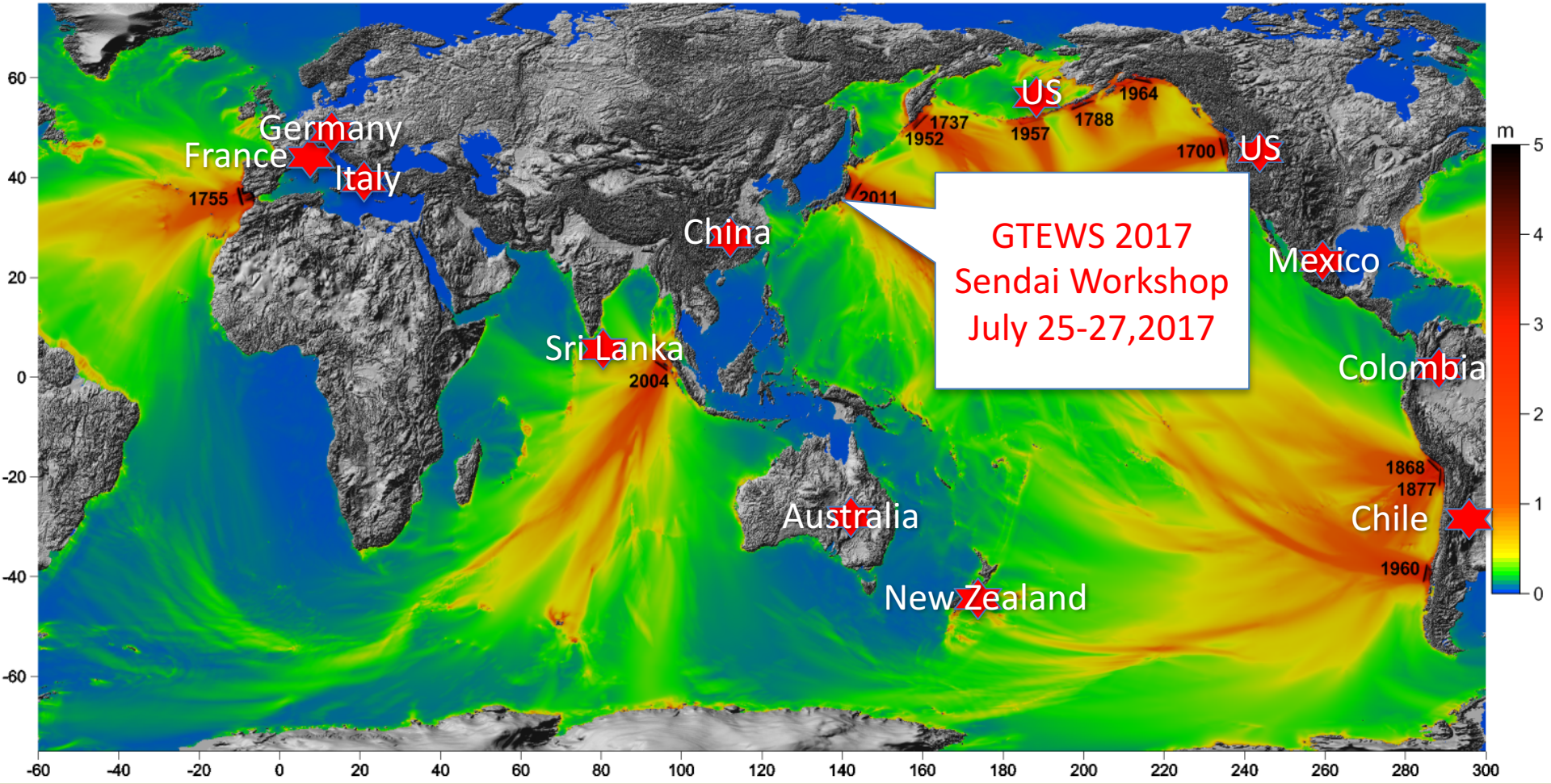
- On April 1,2016 GGOS released a Call for Participation (CfP) in a Working Group for GNSS Augmentation to the Tsunami Early Warning Systems (GATEW). http://kb.igs.org/hc/en-us/articles/218259648-Call-for-Participation-GNSS-Augmentation-to-the-Tsunami-Early-Warning-System

- **One year later, GATEW working group membership includes 16 members from 11 nations.**

- **The CfP for the GATEW working group remains open and membership is growing.**

Slide provided by J. LaBrecque

GTEWS 2017 Workshop on GNSS Tsunami Early Warning Systems



11 Nations
16 member Agencies and Institutions

Slide provided by J. LaBrecque

GGOS Working Group on GNSS Augmentation for Tsunami Warning (GATEW)

Green cells signify GTEWS2017 registration as of May 1, 2017

Country	Organization	Resources	Contact	Email	GTEWS2017
Australia	GeoScience Australia	Large National Real Time GNSS Network	John Dawson	John.Dawson@ga.gov.au	
Chile	U.Chile, Department of Geophysics, CSN	Large National Real time Geodetic and Seismic Network	Sergio Barrientos, Sebastián Riquelme, Juan Baez	sbarrien@dgf.uchile.cl, sebastian@dgf.uchile.cl,jcbaez@csn.uchile.cl	
China	GNSS Research Center, Wuhan University	First Real Time Asian Analysis Center	Jianghui Geng	jgeng@whu.edu.cn	
Colombia	Geological Survey Colombia	Large Real Time GNSS Network, Regional Data Sharing with Brazil, Peru, Panama, Venezuela, COCONet Data Center	Hector Mora	hmora@sgc.gov.co	
France	Institut de Physique du Globe de Paris	Strong research in tsunami coupled ionospheric waves and tracking	Giovanni Occhipinti	ninto.a.paris@gmail.com	
Germany	GeoForschung Zentrum, Department Geoservices	Strong research and development of GNSS Early Warning including Indonesia and Oman projects	Harald Shuh, Jörn Lauterjung	schuh@gfz-potsdam.de, lau@gfz-potsdam.de	
Italy	University of Rome Geodesy and Geomatics	Initiating research in GNSS Tsunami Warning	Mattia Crespi, Augusto Mazzoni	mattia.crespi@uniroma1.it , augusto.mazzoni@uniroma1.it	
Mexico	Instituto de Geofisica, UNAM	Large National GNSS network and analysis system, COCONet Data Center	Enrique Cabral	ecabral@geofisica.unam.mx	
New Zealand	GNS Science	Large National Network	Elisabetta D'Anastasion	E.DAnastasio@gns.cri.nz	
New Zealand	Land Information New Zealand	Large National Network	Dion Hansen	DHansen@linz.govt.nz	
Sri Lanka	Survey Department of Sri Lanka	Strong interest in developing Tsunami Early Warning	P. Sangakkara,Mr A. Dissanayeke	dsggeode7c@survey.gov.lk,addsgc@survey.gov.lk	
USA	Georgia Tech	Significant focus on subduction zone activity and the generation of tsunamis	Andrew V. Newman	anewman@gatech.edu	
USA	Jet Propulsion Laboratory	Real time expertise, Ionospheric mapping, global and operations, earthquake and tsunami warning	Attila Komjathy, Tony Yuhe Song	attila.komjathy@jpl.nasa.gov, Tony.Song@jpl.nasa.gov	
USA	UNAVCO	Global GNSS networks, real time data systems, Global GNSS support	Linda Rowan	rowan@unavco.org	
USA	READI Working Group	NASA-NOAA working group developing GNSS Based Tsunami Warning	Yehuda Bock, Timothy Melbourne	ybock@ucsd.edu, tim@Geology.cwu.edu	
USA	NASA	NASA Solid Earth Science. Provides funding from GNSS Tsunami Warning development. Cooperating with NOAA in this effort.	Gerald Bawden	gerald.w.bawden@nasa.gov	

90% of GATEW Working Group membership has registered to attend the GTEWS2017 Workshop in Sendai.

GNSS TSUNAMI EARLY WARNING SYSTEM WORKSHOP

July 25-27, 2017 • Westin Hotel, Sendai, Japan

First Call for Participation

Workshop Purpose: The past decade has witnessed a terrible loss of life related to large earthquakes and resultant tsunamis in the Indo-Pacific region. New and experimental algorithms based on real-time GNSS data and science now exist to rapidly determine the likelihood that a tsunami will be generated from a large earthquake, to predict their extent, inundation, and run-up, and to track the tsunami as it propagates through the ocean basins. The goals of this workshop are to:

- Identify what GNSS resources (networks, processing centers, telecommunication, etc.) will be necessary to develop real-time GNSS early warning capabilities throughout the entire Pacific Rim region
- Assess data gaps in the current Pacific-wide networks, develop strategies on the best approaches to fill the gaps
- Review the state-of-the-art early warning approaches with an eye towards emergency response community.

The Organizing Committee encourages your participation in a Global Navigation Satellite System Tsunami Early Warning System (GNSS-TEWS) workshop in Sendai. We encourage all interested participants to attend. Some level of travel support will be available to invited US-based speakers. The primary product of the workshop will be a report to identify strategies needed to understand the data needs for a Pacific-wide activity involving the Asia-Pacific Economic Cooperation (APEC) economies as well as other non-APEC economies.

Sponsored by the National Aeronautics and Space Administration
Co-Sponsored by the
- Association of Pacific Rim Universities Multihazards Hub, Tohoku University, Sendai, Japan
- APRU-IRIDeS Multi Hazards Program
- Global Geodetic Observing System

Organizing Committee:
John Rundle (Chair) jbrundle@ucdavis.edu University of California, Davis
Shunichi Koshimura Tohoku University, Sendai, Japan
Yasuka Ohta Tohoku University, Sendai, Japan
John LaBrecque Global Geodetic Observing System
Yuichi Ono Tohoku University, Sendai, Japan
Takako Izumi Tohoku University, Sendai, Japan
Lorraine Hwang University of California, Davis

geodynamics.org/cig/events
For general information, contact: events@geodynamics.org

Slide provided by J. LaBrecque

Focus Area 3
Sea Level Change, Variability, and Forecasting

GGOS Focus Area 3

- Acts as a point-of-contact for services, projects and individuals outside the geodetic community
- Identifies requirements not-yet-fulfilled by GGOS but necessary to reach the objectives of sea-level related science projects
- Demonstrates the value of GGOS to the sea level community

Slide provided by Tilo Schöne

Aims and Objectives of Focus Area 3

- Identification of the requirements for a proper understanding of global and regional/local sea-level rise and variability especially in so far as they relate to geodetic monitoring provided by the GGOS infrastructure.
- to establish links to external organizations (e.g. IOC) and advocate the GGOS contribution to sea level science.
- Identification of practical projects, which will demonstrate the viability, and the importance of geodetic measurements to mitigation of sea-level rise at a local or regional level.

Slide provided by Tilo Schöne

Demonstration Projects of GGOS FA 3

- Bingley et al.: The Use of Continuous GPS and Absolute Gravimetry for Sea Level Science in the UK
- Shum et al.: BELMONT Forum, Assessment of Relative Sea-Level Rise Hazards for the Bangladesh Delta
- Simons et al.: Revisiting the Threat of Southeast Asian Relative Sea Level Rise by Multi-Disciplinary Research
- Consortia of Indonesia (BIG, Bandung University) & Germany (GFZ): (DFG-SPP Sea Level: **Coastal and Regional Sea Level Change and Subsidence - The Hazardous Potential in Indonesia and South East Asia)** and University of Cologne (DFG-SPP Sea Level: **Building adaptive capacity through translocal social capital: Sea level rise and resilience of coastal communities and households in Indonesia) -> http://www.spp-sealevel.de**

Slide provided by Tilo Schöne

Outlook

- Discuss and refine current and future aspects of geodetic contributions for sea level research with groups identified by Focus Area 3
- Work on to identify and contact emerging Focus Area 3 pilot/demonstration projects and inviduals/young researchers
- Identify geodetic monitoring aspects relevant to Focus Area 3
- Coordinate with GGOS Bureau for Networks and Observations about monitoring infrastructure need for sea level research
- Work with GGOS on the implementation of requirements outlined in the “Priorities of installation of continuous GNSS near tide gauges” report

Slide provided by Tilo Schöne

Focus Area 4
Geodetic Space Weather Research

Objectives of the Focus Area

- The **main objectives** of Focus Area 4 can be formulated as:
  1. Improvement in **positioning** and **navigation** by developing high-precision and high-resolution **models** of the **electron density** within the ionosphere,
  2. Improvement of **satellite orbit determination** by developing high-precision and high-resolution **thermospheric drag** models.

  (Ionosphere and thermosphere are the „geodetic“ manifestations of space weather)

- **Additional Statements:**
  1. We understand these objectives with respect to both **fundamental research** and **practical applications**.
  2. Due to **fundamental research** the **running time** of the Focus Area has to be fixed to a **much longer** time span than the IAG period of **four years**.
  3. Furthermore, the **developed ionosphere** and **thermosphere models** can be interpreted as **GGOS products**.

Slide provided by Michael Schmidt

Joint Study Groups (JSG) related to Focus Area 4

- For the **realization** of the objectives of Focus Area 4, at least **two new JSGs** have to be installed.
- Their **topics** could be formulated as:
  - **JSG 1**: **Electron density modelling** of the ionosphere including space weather effects and predictions approaches from the combination of space-geodetic measurement techniques.
  - **JSG 2**: Improvement of **thermosphere models** including physics-based realisations of **thermosphere-ionosphere coupling** processes, in particular for applications in the orbit determination of LEO satellites.
- Already existing IAG- and ICCT-Study Groups and -Working Groups of the **current IAG structure** will provide valuable input for the Focus Area.
- The work within the Focus Area will be carried out in close relation to the **International Association of Geomagnetism and Aeronomy** (IAGA).

Slide provided by Michael Schmidt

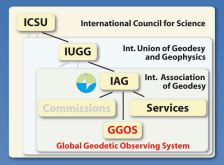
Summary

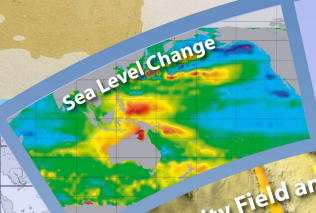
- GGOS is *the* Global Geodetic Observing System
  - Unifies the technique-specific Services of the IAG
    - Coordinates interaction between IAG Services, Commissions, & stakeholders
  - Integrates measurements of Earth's varying shape, rotation, and gravity into one comprehensive observing instrument
    - Target relative accuracy of 10^{-9} or better
- GGOS promotes geodesy
  - Represents IAG within GEO & contributes to GEOSS
  - Organizes meetings
    - Unified Analysis Workshops; Science Workshops; GGOS sessions at conferences
- GGOS promotes international cooperation
  - Next generation geodetic network
    - Design simulations; Call for Participation

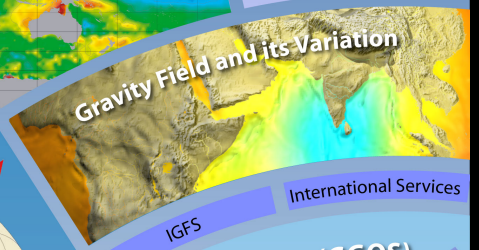
IAG's Global Geodetic Observing System

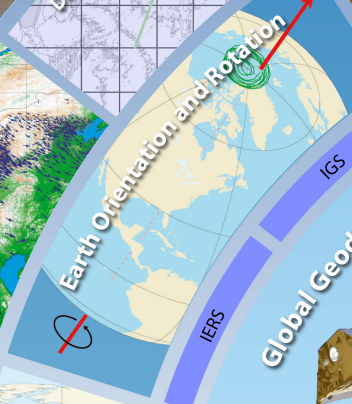
GGOS
http://www.ggos.org

Markus Rothacher (GGOS Chair), Achim Helm (GeoForschungsZentrum Potsdam)
Ruth E. Neilan (GGOS Vice-Chair) (Jet Propulsion Laboratory)
Hans-Peter Plag (GGOS Vice-Chair) (University of Nevada)









International Services

IGFS

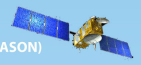
IGS

IERS

ILRS

IVS

Global Geodetic Observation System (GGOS)



Geodetic Space Techniques